Brief information about the project

Name of the project	AP09259023 «Generalized chemical model of warm dense matter»	
Relevance	project contains an original idea, is new and realizes one of the most attractive ideas of the physics of continuous media, when the pair interaction potentials between particles simultaneously determine composition, thermodynamic and transport properties	
Purpose	The project is aimed at developing a generalized chemical model of WDM of arbitrary composition, which allows one to calculate its composition and ionization potential depression, as well as to determine thermodynamic and transport properties. A constructed generalized model will be applied to WDM of hydrogen and carbon.	
Objectives	1	Construct a generalized chemical model of multicomponent media in WDM state
	1.1	Obtain free energy of WDM, which includes microscopic and macroscopic interparticle interaction potentials
	1.2	Determine ionization potential depression of WDM by minimizing its free energy in the case of arbitrary ionization. Consider the limiting cases of weak and strong ionization
	1.3	Determination of ionization potential depression for various substances in WDM states
	2	Hydrogen in WDM state
	2.1	Determine free energy of hydrogen, which consists of free electrons and protons, atoms and hydrogen molecules
	2.2	Calculate composition of warm dense hydrogen in wide ranges of temperature and density by minimizing its free energy. Determine ionization potential depression of atoms and dissociation energy depression of hydrogen molecules
	2.3	Calculate thermodynamic and transport properties of hydrogen in WDM state via macroscopic interaction potentials
	3	Carbon in WDM state
	3.1	Determine free energy of carbon expressed via components number densities
	3.2	Calculate composition of warm dense carbon in wide ranges of temperature and density by minimizing its free energy. Determine ionization potential depression of carbon atoms and ions
	3.3	Calculate thermodynamic and transport properties of carbon in WDM state via macroscopic interaction potentials
Expected and achieved results	using the generalized Boltzmann-Poisson equation, an analytical expression for the free energy of a system containing an arbitrary number of components is obtained, and analytical expressions for the ionization potential depression for various systems are found. In particular, it is found that of the ionization potential depression is significantly affected by the neutral component and, in the case of multiparticle ionization, by the finiteness of the sizes of the ions	
Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if	The project manager is Askar Davletov (**Researcher ID:** O-1078-2014, **ORCID ID:** 0000-0003-0007-968, **Scopus ID**: 6602642543), Doctor of Physical and Mathematical Sciences, Professor, Academician of the National Academy of Sciences of the Republic of Kazakhstan, who is a renowned expert in the field of strongly coupled	

available) and links to relevant profiles	Coulomb systems. His Hirsch index is 12 and the corresponding citation index is 391.
	a foreign researcher, Doctor of Physical and Mathematical Sciences, Professor I.M. Tkachenko (**Researcher ID:** A-4125-2015, **ORCID ID:** 0000-0001-8767-0581, **Scopus ID**: 7006413551) will be involved, who is a world famous specialist in the field of strongly coupled systems with Hirsch index being 15 and the citation index being 622.
	One of the main executors will be a well-known scientist in the field of constructing effective models of interparticle interactions, Doctor of Physical and Mathematical Sciences, Professor Yu.V. Arkhipov (**Researcher ID:** N-4833-2014, **ORCID ID:** 0000-0002-7299-5452**, Scopus ID**: 6603726292), who has the Hirsch index of 12, and the citation index of 377.
	Ye.S. Mukhametkarimov (**Researcher ID:** N-6833-2017, **ORCID ID:** 0000-0003-1381-4532, **Scopus ID**: 55700980900) got his PhD in Science under the supervision of the project manager in 2013, and has more than 10 years of experience in research. His Hirsch index is 4, the citation index is 40.
	L.T. Yerimbetova (**Researcher ID:** O-2204-2014, **ORCID ID:** 0000-0003-3498-8216, **Scopus ID**: 56258671600) got her PhD in Science under the supervision of the project manager in 2019, Her Hirsch index is 3, and the citation index is 21.
	F. Kurbanov (**Researcher ID:** AAZ-5709-2020, **ORCID ID:**0000-0001-7533-5313, **Scopus ID**: 57204898152) is a PhD student, whose scientific supervisor is the project manager. His Hirsch index is 1, and the citation index is 1.
List of publications with links to them	*2021* Articles: Theses and papers at international conferences held: *a) internationally:* 1 Davletov A.E., Kurbanov F., Mukhametkarimov Ye.S., Yerimbetova L.T., Turbekova A.G. Ionization potential depression in partially ionized plasmas // Abstracts of the International Conference on Physics of Nonideal Plasmas 17. – 2021. – P.43. Dresden, Germany. *b) in the Republic of Kazakhstan:* 1 Kurbanov F., Yerimbetova L.T., Turbekova A.G. Free energy of a dense heated substance of arbitrary composition // VIII International Farabiev Readings. – Almaty, 2021 – P.392 (in Russian).
	2022 Articles: Theses and papers at international conferences held: *a) internationally:* 1 Davletov A.E., Mukhametkarimov Ye.S., Yerimbetova L.T., Token N.N., Turbekova A.G. Generalized chemical model for ionization and dissociation in warm dense hydrogen // Abstracts, Strongly Coupled Coulomb Systems. – July, 2022. – P. 48. Dresden, Germany. *b) in the Republic of Kazakhstan:* 1 Token N., Mukhametkarimov E., Turbekova A. Thermodynamic properties of dense heated hydrogen // IX International Farabiev Readings. – Almaty, 2022 – P.377 (in Russian).

	2023 Articles: *a) In journals with a non-zero impact factor indexed in Thomson Reuters:* 1 Davletov A.E., Arkhipov Yu.V., Mukhametkarimov Ye.S., Yerimbetova L.T., Tkachenko I.M. Generalized chemical model for plasmas with application to the ionization potential depression // New J. Phys. – 2023. – Vol. 25, Art. No. 063019 (8 p.), doi: 10.1088/1367-2630/acd445 (IF 3.3, Q2, WoS) Davletov, A., Yerimbetova, L., Mukhametkarimov, Y., & Kissan, A. Impact of neutrals on the plasma screening length // Journal of Plasma Physics. – 2023. – Vol. 89 (5), Art. No. 905890501 (16 p.). doi:10.1017/S0022377823000958 (IF 2.5, Q2, WoS)
Patents	-